The Research of Maximum Power Point Tracking Control Algorithm for Photovoltaic Cells Based on Improved Perturbation-Observation Method

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Abstract

The paper analyses the voltage-current characteristics of photovoltaic (PV) cells to study the maximum power point tracking control algorithm. This article proposes a kind of improved maximum power point tracking control algorithm for PV cells, based on nearly linear dP/dU and I as well as PV array operating at stable area. A new judegment condition to confirm the maximum power point is researched in the algorithm, which combines constant voltage method with perturbation-observation method. The stability of PV system is improved compared with traditional perturbation-observation method. The algorithm is theoretically derived and simulated by MATLAB. The results of simulation show that this new algorithm can eliminate oscillation near the maximum power point.

Keywords

PV Cells; Maximum Power Point Tracking (MPPT); Perturbation-Observation Method

Introduction

When the energy and pollution problems are highlighted, development of new energy is the key whether each country can develop sustainable. Due to solar energy has many advantages, which is noiseless, pollution-free and available widely, so using solar energy can defuse serious shortage situation of global energy. In order to maximize using solar energy, the method of maximum power point tracking（MPPT） is brought into PV power system. It makes output power of PV array maximize. The PV array can be regards as a set of direct current power supply. Because solar cells have nonlinear characteristics, the maximum power point may be moved when the strength of the sun light and the environmental temperature change. Therefore, the research of maximum power point tracking control for PV array is of practical value.

There are two ways for MPPT control algorithm. One way is that seeks maximum power point by the first derivative the power respect to the voltage and making it zero (dP/dU=0). Another way is that seeks maximum power point through step by step adjusting detection continuously. Some methods are applied usually, such as constant voltage control, perturbation-observation, incremental conductance, and fuzzy control algorithm. It is complex for the way to seek the maximum power point by dP/dU=0 method, according to the known output characteristics of PV cells. This method needs to use Newton iteration method to get the solution and costs much time to simulating it. MPPT algorithm is used often to seek the maximum power point, which combines traditional constant voltage with perturbation-observation method, or incremental conductance method, by changing operating point continuously and detecting output power. But traditional constant voltage method is of oscillating problem near maximum power point and affects the stability of PV system. This article proposes a new kind of judgment condition to confirm maximum power point, under the situation of PV cells operating within stable area as well as dP/dU and I being of linear relation. This judgment condition can solve oscillating problem compared with traditional perturbation-observation method and improves the stability of PV system. The author simulated this new algorithm by MATLAB software and proved it being of effective.

Analysis of Characteristics for PV Cells

The PV cells are key elements of PV generation system. Analysis of PV cells is basis for researching maximum power point tracking control algorithm. The electric-generation principle of PV cells comes from PV effect, which of its physic structure is similar to PN junction in diodes. When the sun light shines on PV cells, PN junction can produce voltage. The power of one PV cell is very small. It is necessary for PV array to get greater power by connecting large number of PV cells in series. The equivalent circuit of PV cells is given in Fig.1.

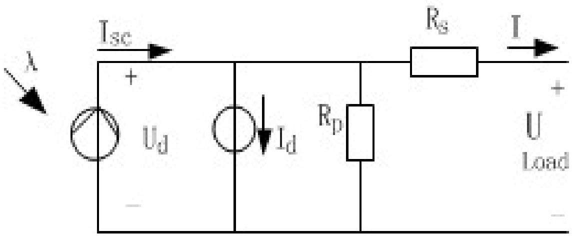


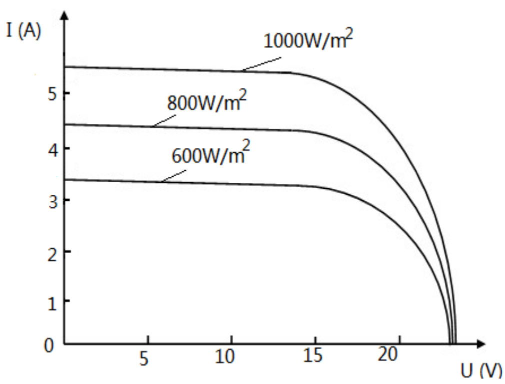
FIG.1 PV CELLS EQUIVALENT CIRCUIT

The U-I output characteristics of PV cells is described as formula 1.

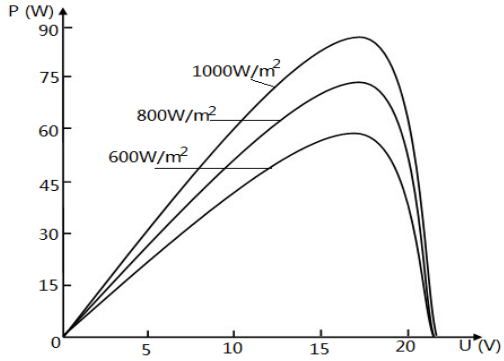
$$I = I_{sc} - I_d[e^{\frac{q(U+IRs)}{AKT}} - 1] - \frac{U+IRs}{Rp} \qquad (1)$$

Rs and Rp indicate series and parallel resistance respectively in formula 1. T is cells temperature, q is electron charge. A is a non-dimensional fitted curve constant (1≤A≤2), A depends on output voltage of PV cells. K is a Boltzmann constant (K=1.38×10-23J/K). Isc is photo-generated current and Id is reversed saturation leakage current in diodes. The value of I_{sc} and I_d also depend on intensity of the sun light and environmental temperature.

The typical I-U and P-U output characteristics curve of PV cells under different light intensity is shown in Fig2.



(a)I-U CHARACTERISTICS CURVE



(b)P-U CHARACTERISTICS CURVE

FIG.2 PV CELLS CHARACTERISTICS CURVE

It can be seen that I-U and P-U output characteristics curve of PV cells are considerable nonlinear. We can find from P-U curve that PV cells have maximum power point when environmental condition is kept constant, but the maximum power point can be moved under different condition. MPPT algorithm makes PV cells operate near maximum power point by changing external load characteristics of PV cells.

This a general, when we research complex PV grid-connected system we use the simple model of PV cells commonly, and ignore tiny decline of output voltage caused by serial and parallel resistances of PV cells. This article discusses the control algorithm of PV system by using simple model, thus the characteristics formula is simplified as formula 2.

$$I = I_{sc} - I_d[e^{\frac{q(U+IRs)}{AKT}} - 1] \qquad (2)$$

We can obtain the load voltage as formula 3.

$$U = \frac{AKT}{q}\ln\frac{I_{sc}+I_d-I}{I_d} \qquad (3)$$

We can obtain output power of PV cells as formula 4.

$$P = UI = U[I_{sc} - I_d(e^{\frac{qU}{AKT}} - 1)] \qquad (4)$$

Taking the differential for equation 3 we get formula 5.

$$\frac{dI}{dU} = -\frac{q}{AKT}(I_{sc}+I_d-I) \qquad (5)$$

We know Isc+Id-I>0 from physic structure of PV cells and the principle of its equivalent circuit model, therefore dI/dU<0.Then it is known that I-U function

decreases monotonously.

Taking the differential for equation 4 we obtain formula 6.

$$\frac{dP}{dU}=I+\frac{dI}{dU}U=(1+\frac{qU}{AKT})I-\frac{qU}{AKT}(I_{sc}+I_d) \quad (6)$$

Due to PV array operates near maximum power point, U can be considered as a constant approximately, therefore dP/dU is a first degree function of argument I from equation 6. Because of dP/dU-I displays linear relation near maximum power point, so we can seek maximum power point .When dP/dU=0 this is a maximum power point, which its differential for both sides of the point is opposite sign. We take the differential for U again as equation 7:

$$\frac{d^2P}{dU^2}=\frac{dI}{dU}+\frac{dI}{dU}*\frac{qU}{AKT}+\frac{q}{AKT}(I-I_{sc}-I_d) \quad (7)$$

Owing to dI/dU<0，I-Isc-Id<0，therefore $d^2P/dU^2<0$, dP/dU decreases monotonously, dP/dU has only one zero point, P-U curve has only one extreme point, and that is maximum point, which its differential for both sides of the maximum point is opposite sign.

Improved Perturbation-observation Method

The judgment condition for seeking maximum power point is dP/dU=0 at traditional perturbation-observation method. The algorithm which combines constant voltage method with perturbation-observation method uses constant voltage to keep PV array operating near the maximum power point, and adopts perturbation-observation method to increase the output power of PV system. We increase or decrease the voltage near maximum power point, and detect the output power to confirm the direction of power variation, so as to adjusting control signal to reach the maximum power point. It is not easy to reach the point (dP/dU=0) exactly through the step of perturbation-observation method, so it is possible to cause oscillating near maximum power point.

Owing to output characteristics curve of PV cells has only one extreme point, the calculating value of dP/dU by adding step can be regards as a judgment condition for maximum power point of PV cells output.

Therefore this article proposes a new judgment condition for maximum power point tracking given as formula 8.

$$\frac{dP}{dU}(k)*\frac{dP}{dU}(k-1)<0 \quad (8)$$

$\frac{dP}{dU}(k)$ is a value after adding perturbation step, and $\frac{dP}{dU}(k-1)$ is a value before adding perturbation step.

When the system meets the formula 8, PV cells operate just at the maximum power point. Then this method can eliminate oscillation near maximum power point, rather than being not easy to seek the point (dP/dU=0) exactly.

PV power system operates at the cross point existed in power supply and load from reference[2]. The stable operating condition of PV power system must meet formula 9.

$$[\frac{dP}{dU}]_{load} > [\frac{dP}{dU}]_{source} \quad (9)$$

Accordingly the normal operating point of PV power system exists in dP/dU<0 area usually.

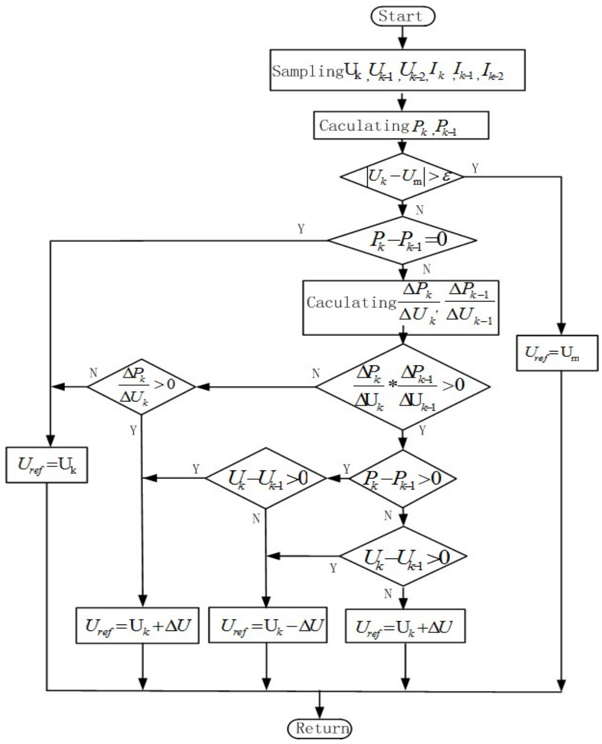


FIG.3 IMPROVED PERTURBATION-OBSERVATION METHOD CONTROL FLOW CHART

Using above judgment condition for maximum power point and combining constant voltage with perturbation-observation method, we can obtain the control flow chart of improved perturbation-observation method (see in Fig.3).Input variables are current and voltage of PV cells, output variable is

reference voltage U_{ref}. U_k, I_k and P_k is PV cells voltage, current, and power at K moment respectively. ΔP_k andΔU_k are difference voltage and difference power of PV cells between K and K-1 moment. ΔU is voltage perturbation step, Um is maximum power voltage under standard condition of PV cells,$\varepsilon$is a smaller constant based on experience settings. By the analogy, the variables at K-1 moment are similar to variables at K moment.

Simulation and Verification

In order to verify the availability for the new algorithm of maximum power point tracking control, the perturbation-observation method is applied to the simulation for PV generation system. The simulation structure model is shown in Fig.4.

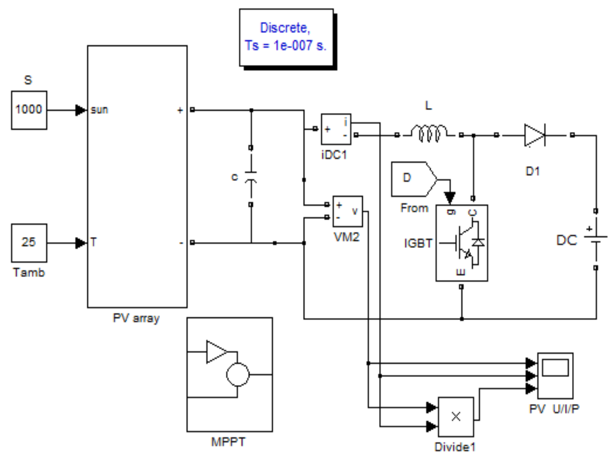
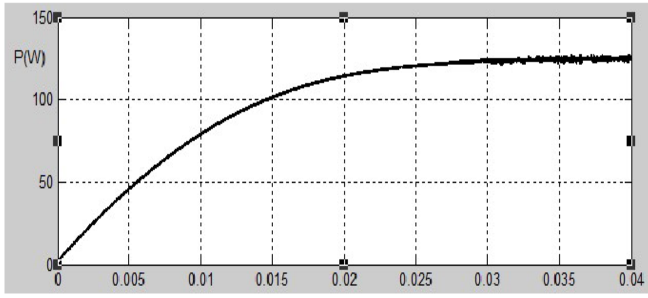


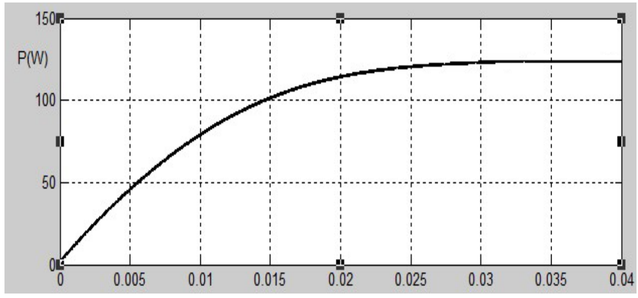
FIG.4 SINGLE PHASE PV SIMULATION MODEL

The PV cells model is built up under the MATLAB platform.Then we connect it to the chopper circuit of PV generation system to realize maximum power point tracking control. DC/DC transformation adopts closed loop control for PV cells voltage. The reference output voltage from MPPT algorithm block is a given voltage value. For PV cells model used in simulating, its light intensity is 1000W/m^2 , the room temperature is 25℃, output maximum power is 126.7W. We obtain the simulating waveform as shown in Fig.5, by using traditional perturbation-observation method (see in Fig.5(a)) and improved perturbation-observation method (see in Fig.5(b))respectively to carry the maximum power point tracking control.

We can see that these two kinds of method can make PV cells operate at the maximum power point from the simulating figure. But there is obvious oscillating near the maximum power point through comparing Fig.5 (a) with (b), if we use the traditional perturbation-observation method (see Fig.5 (a)). The improved perturbation-observation method can remove the oscillating near the maximum power point effectively (see Fig.5 (b)).



(a)TRADITIONAL PERTURBATION-OBSERVATION METHOD SIMULATION WAVEFORM



(b) IMPROVED PERTURBATION-OBSERVATION METHOD SIMULATION WAVEFORM

FIG.5 DIFFREENT MPPT ALGORITHM SIMULATION WAVEFORM

Conclusion

This article proposes a new judgement condition to confirm the maximum power point. It improves the traditional perturbation-observation method. This new algorithm eliminates the output power oscillation near maximum power point for PV generation system. The simulating results verify that the improved perturbation-observation method is of availability , and the stability of PV power system is also enhanced.

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